SPECTRAL RESPONSE OF NITROGEN (N) FERTILISED MATURE OIL PALM (ELAEIS GUINEENSIS) AND ITS RELATIONSHIPS TO CELL MORPHOLOGIES

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Spectral response of nitrogen (N) fertilised mature oil palm (*Elaeis guineensis*) and its relationships to cell morphologies

By

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CERTIFICATION

This research entitled **"Spectral response of nitrogen fertilised mature oil palm (*Elaeis guineensis*) and its relationships to cell morphologies"** was completed by Wafi Ahmad Tarmizi (176334) and submitted to the Faculty of Agriculture, Universiti Putra Malaysia in fulfilment of the requirement of PRT4999 final year project for the award of the degree in Bachelor of Agricultural Science

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Forever I stand on their shoulder, forever I rest under their shadow.

Magni Nominis Umbra

Yours truly;

Wafi Ahmad Tarmizi

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Abstract

Nitrogen (N) is uptake by oil palm (*Elaeis guineensis*) depends on a few factors including palm age. N is consumed in every plant parts but most importantly it is used in the synthesis of chlorophylls. Chlorophyll is often used to determine plant N status in non-destructive sampling. Oil palm physiological responses to N treatment are well studied but the spectral response associated with it is poorly understood. It is suspected that the basis of the spectral response in relation to N comes from the oil palm cell morphologies. Opportunities has presented itself to study the effects of N treatment on the cell morphologies and to link this to the spectral response obtained through multiple sensors such as SPAD and spectroradiometer. Two experimental sites belonging to United Melaka Berhad Plantation with oil palm age 12 and age 15 were chosen. Each site was randomly divided into split plot of N treatment. The treatment was 0 kg, 1 kg, 2 kg of N. leaf cell structure and spectral data (SPAD and reflectance) from frond 9 and 17 of the oil palm was collected and analysed. The same frond was also subject to histological procedure and 10µm slides was analysed and correlated to spectral data. It was found that cell density played indirect but an important role in partially explaining the spectral readings. Cell density was influenced by both N treatment and palm age. Increasing N treatment increased cell hyperplasic but this may not have direct effect on spectral readings, rather spectral readings was indirectly effected by cell density by the amount of cell that received light directly. The region of 700 – 1350nm have good correlation for chlorophyll prediction. Cell density however, have weak correlation with any wavelength with the r value ranging from r= - 0.6 to 0.2.

Chapter 1

1.0 Introduction

1.1 Introduction

One of the most economically important plantation crop in Malaysia and the South East Asian region is oil palm (*Elaeis guineensis* Jacq.). In Malaysia, the hectarage of oil palm planted is more than 1 million hectare with the estimated production of crude palm oil (CPO) in the range of over 8 million tonnes (MPOB, 2017). Given its economic importance, oil palm physiology is studied extensively. Its general growth physiology is well studied and known. The general recognized palm oil growth stages are immature, young mature, mature, and old. It is known that each growth stage has different nutrient demands to maintain yield. This nutrient requirement is usually specific to location and is determined through soil analysis. An example of oil palm nutrient demand on N, P, K, Ca, and Mg is given in Table 1.

Table 1: Nutrient demand in oil palm for 148 palms ha^{-1}

Period (yrs)	Nutrient demand (kg ha^{-1} yr^{-1})				
	N	P	K	Mg	Ca
0-3	40	6	55	7	13
3-9	191-267	32-42	287-387	48-67	85-114
0-9	1266-1722	210-270	1887-2487	309-423	549-723

Note: Adapted from Fairhurst and Härdter (2003)

Even though nutrient is given in sufficient amount, environmental conditions, oil palm health, and oil palm growth stage can affect the so called "internal nutrient partitioning" in the plant which also effects the growth and yield of the plant. One of the important nutrient that is partitioned and consumed in large amount is nitrogen (N). N is considered as a mobile element and rarely its deficiency symptoms will be seen in young leaves unless there is very severe NO_3^- or NH_4^+ deficiency in the soil or the nutrient somehow become unavailable.

Nitrogen is used in every plant organs and parts but the organs that consume N the most other than the fruit is the leaves (Barker, 2015). The chlorophyll pigment in the leaves contain up to 4 N molecule per chlorophyll pigment and considering there 6 types of chlorophyll (a to f), the leaf is major N sink. Oil palm greenness is a good indicator of the overall health of the palm since the chlorophyll content is directly correlated to the plant health (Carter, 1993).

There are many methods to assess chlorophyll content. Currently, the most popular method is a light-based assessment either through light transmission, reflectance, or absorbance. Light based method, although an indirect method of measuring N foliar content, is fairly accurate since

75% of foliar N is concentrated in the chlorophyll pigment (Barker, 2015). Some methods of light based measurement is more accurate and suitable than others. For example, recent study by Amiruddin et al. (2014) and Salim (2014) were in agreement that SPAD data have low correlations in mature oil palm, but spectroradiometer such as the GER 1500 device produce marginally better results (Amiruddin et al., 2017) and can be improved with the use of indices such as vis+NIR and G+R+NIR (Amiruddin et al., 2017). Of course, the more accurate method of determining foliar N is through chemistry based nutrient analysis. Nutrient analysis is although highly accurate, is very time consuming and can be expensive. Nutrient analysis is also a destructive method which may not be an option in trials where there is limited number of plants. Indeed, the attractiveness of spectral based of N determination are quick and easy, non-invasive, and instantaneous result. It is worth mentioning that nutrient analysis is important in confirming and calibrating light based pigment analysis.

In using light based method in determining oil palm foliar N, it is important to understand and research the mechanism in which light interacts with leaf cells. To date no such research has been done on oil palm or even the family aracaceae (palmae). The closest research was done by Slaton et al. et al. (2001) on angiosperm. Their finding is interesting in that they found correlation between areas on the surface of mesophyll cell expose to the intercellular air space over the total leaf area in the 800nm reflectance range. Should this relationship be true for oil palm, new indices that include the spectral reflectance at 800nm can be included into the current indices to further increase the accuracy of the predicted foliar N. As such a histological sample of leaves can be examined to evaluate the effects of N treatment on the cell structure and thus elucidate the relationship between spectral reading and the cell structure. The cell can either become

hypertrophic or hyperplasic under various N treatments. However, the oil palm being a perennial crop, it does not have distinct nutrient partitioning indicator and this makes the prediction of foliar N difficult. As such it is worth investigating the relationship between cell, N treatment, and the spectral reflectance.

1.2 Objectives

The purpose of this study is to examine the relationship between cell morphology, its reflectance, and chlorophyll count. The specific objectives are:

1.2.1 To characterise leaf cell morphologies of N fertilized mature oil palm

1.2.2 To elucidate the relationship between leaf cell morphologies with the chlorophyll content.

1.2.3 To examine the relationship between cell properties with reflectance data obtained from multiple proximal sensors

Reference

Amirruddin, A., Muharam, F., &Zaharah, A. (2014). Evaluation of multiple proximal sensors for estimating nitrogen nutritional content of matured oil palm. Asian Journal of Plant Sciences, 13(4/8), 136-146.

Amirruddin, A. D., Muharam, F. M., &Karam, D. S. (2017). Evaluation of ground-level and space-borne sensor as tools in monitoring nitrogen nutrition status in immature and mature oil palm. Journal of Plant Nutrition, 00-00.

Amirruddin, A. D., Muharam, F. M., &Mazlan, N. (2017). Assessing leaf scale measurement for nitrogen content of oil palm: performance of discriminant analysis and Support Vector Machine classifiers. International Journal of Remote Sensing, 38(23), 7260-7280.

Apichatmeta, K., Sudsiri, C. J., & Ritchie, R. J. (2017). Photosynthesis of Oil Palm (Elaeis guineensis). 214(Supplement C), 34-40.

Awalludin, M. F., Sulaiman, O., Hashim, R., & Nadhari, W. N. A. W. (2015). An overview of the oil palm industry in Malaysia and its waste utilization through thermochemical conversion, specifically via liquefaction. 50(Supplement C), 1469-1484

Barker, A. V., &Pilbeam, D. J. (2015). Handbook of plant nutrition: CRC press.

Buschmann, C., & Nagel, E. (1993). In vivo spectroscopy and internal optics of leaves as basis for remote sensing of vegetation. International Journal of Remote Sensing, 14(4), 711-722.

Carter, G. A. (1993). Responses of Leaf Spectral Reflectance to Plant Stress. American Journal of Botany, 80(3), 239-243.

Fairhurst, T., &Härdter, R. (2003). Oil palm: management for large and sustainable yields. Oil palm: management for large and sustainable yields.

Gates, D. M., Keegan, H. J., Schleter, J. C., & Weidner, V. R. (1965). Spectral Properties of Plants. Applied Optics, 4(1), 11-20.

Gitelson, A. A., Gritz, Y., &Merzlyak, M. N. (2003). Relationships between leaf chlorophyll content and spectral reflectance and algorithms for non-destructive chlorophyll assessment in higher plant leaves. Journal of plant physiology, 160(3), 271-282.

Gitelson, A. A., Thenkabail, P. S., Lyon, J. G., &Huete, A. (2011). Hyperspectral Remote Sensing of Vegetation.

Goh, K., Härdter, R., Fairhurst, T. H., &Hardter, R. (2003). Oil Palm – Management for Large and Sustainable Yields.

Gu, J., Chen, Y., Zhang, H., Li, Z., Zhou, Q., Yu, C., Yang, J. (2017). Canopy light and nitrogen distributions are related to grain yield and nitrogen use efficiency in rice. Field Crops Research, 206, 74-85. doi:10.1016/j.fcr.2017.02.021

Hacke, U. G., Plavcová, L., Almeida-Rodriguez, A., King-Jones, S., Zhou, W., & Cooke, J. E. K. (2010). Influence of nitrogen fertilization on xylem traits and aquaporin expression in stems of hybrid poplar. Tree Physiology, 30(8), 1016-1025. doi:10.1093/treephys/tpq058

Hatfield, J. L., Gitelson, A. A., Schepers, J. S., &Walthall, C. L. (2008). Application of Spectral Remote Sensing for Agronomic Decisions. Agronomy Journal, 100(Supplement_3), S-117-S-131. doi:10.2134/agronj2006.0370c

John, G. P., Scoffoni, C., & Sack, L. (2013). Allometry of cells and tissues within leaves. American Journal of Botany, 100(10), 1936-1948. doi:10.3732/ajb.1200608

Lelong, C. C., Roger, J.-M., Brégand, S., Dubertret, F., Lanore, M., Sitorus, N., . . .Caliman, J.-P. (2010). Evaluation of Oil-Palm Fungal Disease Infestation with Canopy Hyperspectral Reflectance Data. Sensors, 10(1), 734.

Manurung, A. N. H., Sudradjat, &Hariyadi. (2015). Optimization rate of Organic and NPK compound fertilizer on second year Immature oil palm. Asian Journal of Applied Sciences, 03(03), 375 -381.

Mohidin, H., Hanafi, M. M., Rafii, Y. M., Abdullah, S. N. A., Idris, A. S., Man, S., . . . Sahebi, M. (2015). Determination of optimum levels of nitrogen, phosphorus and potassium of oil palm seedlings in solution culture. Bragantia, 74, 247-254.

Pardon, L., Bessou, C., Nelson, P. N., Dubos, B., Ollivier, J., Marichal, R., Gabrielle, B. (2016). Key unknowns in nitrogen budget for oil palm plantations. A review. Agronomy for Sustainable Development, 36(1), 1-21. doi:10.1007/s13593-016-0353-2

Pardon, L., Huth, N. I., Nelson, P. N., Banabas, M., Gabrielle, B., & Bessou, C. (2017). Yield and nitrogen losses in oil palm plantations: Main drivers and management trade-offs determined using simulation. 210(Supplement C), 20-32.

PeÑUelas, J., Filella, I., Biel, C., Serrano, L., &SavÉ, R. (1993). The reflectance at the 950–970 nm region as an indicator of plant water status. International Journal of Remote Sensing, 14(10), 1887-1905.

Salim, M. Z. (2014). Reliability Of Spad Meter To Indicate Foliar Nitrogen Content In Mature Oil Palm. (Undergraduate), University Putra Malaysia,

Siallagan, I. (2015). Optimasi dosis pupuk organic dan NPK majemuk pada tanaman kelapa sawit belum menghasilkan. JurnalAgronomi Indonesia (Indonesian Journal of Agronomy), 42(2).

Sims, D. A., &Gamon, J. A. (2002). Relationships between leaf pigment content and spectral reflectance across a wide range of species, leaf structures and developmental stages. 81(2–3), 337-354.

Slaton et al., M. R., Raymond Hunt, E., & Smith, W. K. (2001). Estimating near-infrared leaf reflectance from leaf structural characteristics. American Journal of Botany, 88(2), 278-284.

Uwumarongie-llori, E. G., Sulaiman-llobu, B. B., Ederion, E., Imagie, A., Imoisi, B. O., Garuba, N., &Ugbah, M. (2012). Vegetative growth performance of oil palm (Elaeisguineensis) seedling in response to inorganic and organic fertilizers. Greener Journal of Agricultural Sciences, 02(02), 026-030.

Yoder, B. J., & Pettigrew-Crosby, R. E. (1995). Predicting nitrogen and chlorophyll content and concentrations from reflectance spectra (400–2500 nm) at leaf and canopy scales. Remote sensing of environment, 53(3), 199-211.